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FLARES AND EMISSION LINES OF THE SOLAR CORONA

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FLARES AND EMISSION LINES OF THE SOLAR CORONA

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ABSTRACT

In the course of simultaneous investigations of solar flares and solar corona emission lines, it was found that the latter are intense near the flare. The yellow coronal line 5694 A glows more brightly near the flare; it is 8 to 10° from sunspots and the area it covers is substantially greater than that of the latter. Coexistence of lines with different ionization potentials is possible in certain cases, which corroborates the theoretical opinion of Elwert, though contradiction is found in structural photos [8].

* * *

COVER TO COVER TRANSLATION

The problem of simultaneous study of flares and corona emission lines is exceedingly difficult. However, in the course of successful observations it is possible to ascertain, for example, how matter ejection from chromosphere to corona takes place and how such process influences the corona lines' emission.

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* Vspyshka i emissionnye linii solnechnoy korony.

Inasmuch as it has been established by Lyot and Waldmeier works [1, 2] that the glow of the yellow coronal line 5694 Å is connected with sunspots while chromospheric flares occur in the neutral zone near spots [3], we observed in the course of 1961 the activity of the occurring sunspots, particularly when they approached one of the edges of the Sun. At the same time photographing of a series of corona emission lines was effected with the aid of an improved- 7 Å/mm dispersion spectrograph on a high-altitude (2600 m) coronal station. On the other hand, the chromospheric flares appearing in the sunspot region near the edge of the disk were cinematographed with the aid of a chromosphere-photosphere telescope AFR-2. The simultaneous occurrence of a limb flare and spots at the solar disk edge in the presence of of coronal weather is an exceedingly rare phenomenon. One such flare and the corona emission lines could be registered in the course of numerous months and in another case there was a spot group at the disk without flare, where coronal emission lines were also obtained.

Two flares, giving characteristic ejections in the corona, took place on 12 July 1961 in the region of disintegrated spots at the disk's edge at the 285° position angle.

The spot having occurred on 1 July at the eastern edge developed violently in the course of a few days, the magnetic field intensity reaching 2600 degrees. A series of tiny spots were noted around a central spot [4], ahead of a spot — filament, which was photographed on 12 June at the western edge in the form of a quiescent prominence. The spot began to disintegrate on the previous day, and on 12 July it gave two flares at the very edge of the disk.

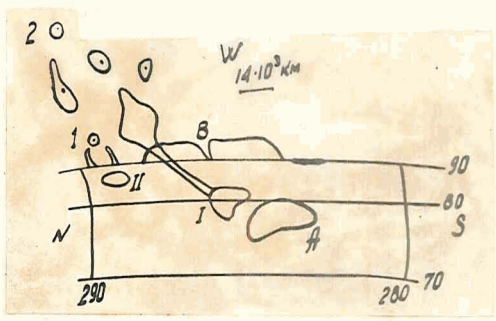


Fig. 1

The diagram of the details photographed on 12 July at 04 49 hrs UT, the coordinate net of 70, 80 and 90° longitude and 20 and 10° latitude, and the corona region are given in Fig. 1. Flares I and II occurred in the spot region (A). The quiescent prominence 8 is designated in Fig. 1. The remaining details concern those of ejections.

In observing the flares and the attending matter ejections from the chromosphere in the corona we paid attention to the behavior of the quiescent prominence. The processing of materials has shown that, although the prominence was near the spot, flares and more particularly near the ejections, it was glowing nearly independently from these phenomenas (see Table hereafter).

Observation Time	Base of the Prominence	Height in km
02 12 hrs	3.6°	$8.7 \cdot 10^3$
04 50	4.2	$8.9 \cdot 10^3$
04 59		
05 12	3.8	$8.3 \cdot 10^3$

As may be seen from the Table, neither the base nor the height of the prominence practcally varied. A slight base widening at the moment of ejection took place on account of ejection superimposition on the northern edge of the prominence.

The flare I of force 1 occurred at 04 hrs 34.5 min UT at the northwestern edge of the spot, at 11° from that of the Sun. In the course of its development it had two identical brightness maxima, respectively at 4 h 41.5 min and at 4 h 54 min. At 05 hrs 8.5 min the flare ceased to glow. The curve of flare I brightness variation in the 04 34 — 05 08 hr interval is plotted in Fig. 2.

Flare II occurred at 04 39 hrs UT about 3° from the limb and vanished at 04 54 hrs after reaching the glow maximum at 04 42 hours.

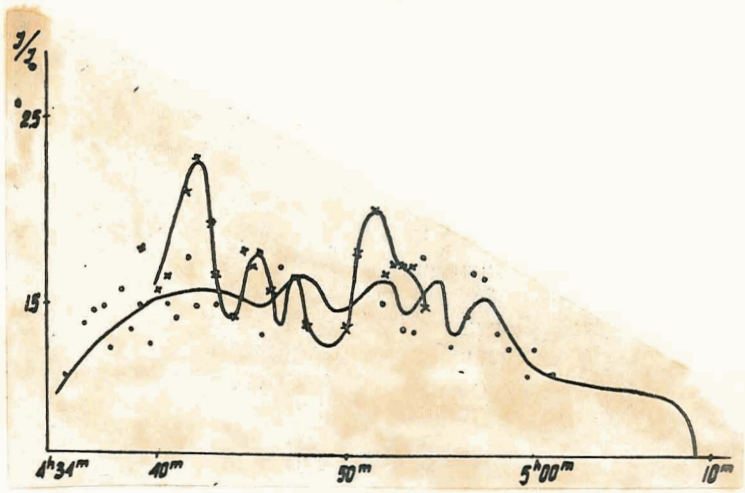


Fig. 2

The results of flare II photometry are given in Fig. 2 in the form of a curve of brightness variation with time. The curve of flare II brightness is above that of flare I, for the former is 1.2 times brighter than the latter. Because of the impossibility of determining somewhat reliably the surface of the flare, its force was not ascertained. Flare II also had two brightness maxima.

The flares gave several ejections into the corona. These ejections took place with an insignificant lag by comparison with the moment of flare appearance. The ejections are shown in Fig. 1. The characteristic angles, carefully studied further, are designated by the numbers 1 and 2.

As of 04 39 hrs a rise of the arc resting at the end on flares I and II could be observed on frames with normal exposure (exposure time was increased for nodes in the corona, remaining normal in the intervals). The brightness of the arc, gradually increasing in all its mass, reached 0.2 of the brightness at the center of the disk at 04 h 42.5 min – $\left(\frac{I_{pc}}{I_{\odot}} = 0{,}2\right)$ – and then began to drop. The arc was reliably observed till 4 h 44.5 min. Its height above the limb at maximum moment of brightness was $26 \cdot 10^3$ km.

Presented is in Fig. 3 the picture observed at the moment 4 h 42 m (a) and 4 h 48 m (b). The ejection jet from flare I is continuous, while that of flare II consists of highly situated nodes, while the summit of ejection I jet is at the level of the lower angle. At the base of flare II ejection a compact matter glows on the limb, whose height is equal to that of the quiescent prominence.

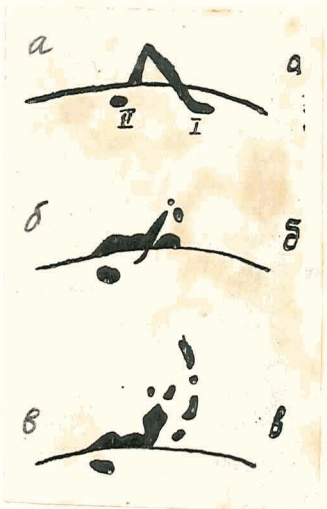


FIG. 3.

The pattern of the state of the arc at 4 h 49 min is given in Fig.1. A node separates from the summit of the two jets of flare I ejection, while the base of flare II thickens into the node 1. Further one may follow the variations of the jets of both flares: their summits coincide, forming an upward extending compressed arc. If the jet was quiet at the beginning, at 4 h 49 min it disintegrated into separate nodes.

Soon the nodes of flare I disappeared and the brightness of the remaining base of ejection I and of the node of ejection II strengthened.

At 05 03 hours, after a strong brightening of the node 2 of the ejection II, a bright column formed along the direction of the ejection. The column split symmetrically into three nodes at 05 06 hours, after gradually losing its brightness. The base of the ejection 1 outstripped the node of the ejection II in the rate of brightness drop. By 06 12 hours nothing was left of the eruption.

Analysis of the material obtained indicates that on 12 July 1961 the eruption did not constitute two ejections of two independent flares, but ejections of a single flare I. The second flare is the result of the action of the first flare after ejection of matter from the chromosphere under the effect of electromagnetic forces. It is obvious that only such an assumption provides the explanation as to why the basic jets of the two ejections kept a common summit during the total observation time, and also why the occurrence of flare II preceded the appearance of its ejection.

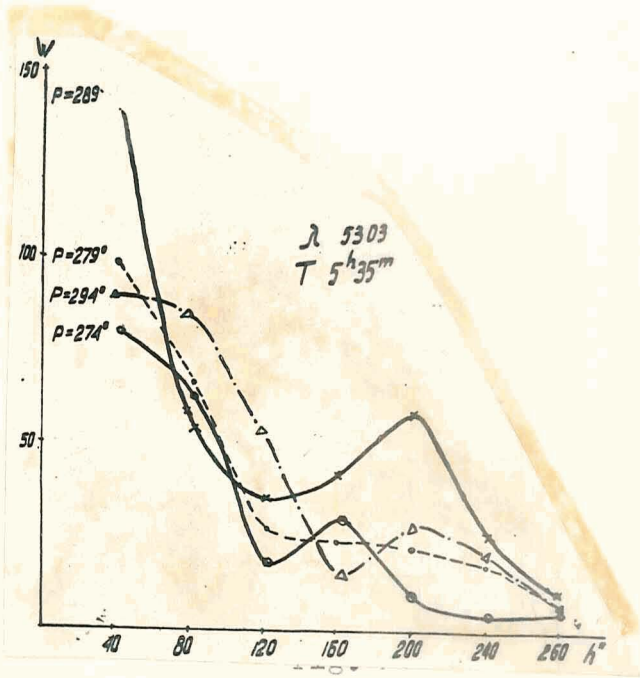
At the beginning of the observation (at 04 42 hrs) arc (a) was clearly apparent between the two flares; this arc developed further and then disintegrated into separate nodes, keeping the general contour of arc I. Something similar was observed by Elliot, Ellison and al [5]. However, it remains incomprehensible why region 2 exceeded region I in brightness if the former is the corollary of the action of the initial flare I. It is likely that a further plasma heating took place here, which has in its turn influenced the corona. The results of photometry of corona spectrum photograph in the line 5303 Å, obtained with a radial slot in position angles 274, 279, 289 and 294° are presented in Fig. 4. The line 5303 Å was observed over a distance of more than 4 minutes of the arc.

The values of the equivalent width are in the ordinate axis (Fig. 4), the observed height in seconds of the arc from the Sun's edge — in abscissa. The course of line 5303 Å brightness is nearly identical in the position angles where the chromosphere is quiescent. In the 289° region, where the flare and the ejection took place, the brightness of the line 5303 Å increased

and the course of brightness changed with the distance (photographing took place after the maximum phase of the flares — at 05 35 hours).

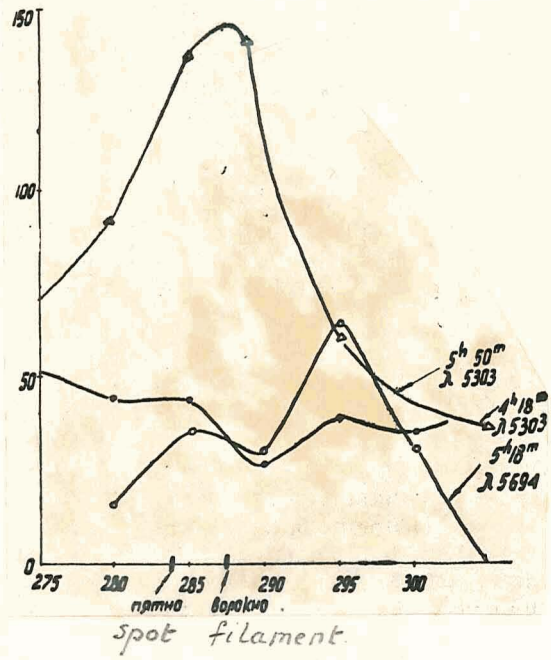
The brightness maximum occurred at the approximate distance of three arc minutes or slightly above.

In the 294° position angle, where no flare took place, the course of brightness variation with the distance from the edge reminds of the pattern having taken place in the 289° region.



Presented are in Fig. 5 the data of brightness measurement of the green coronal line before and after the flare, and also the photometric data of the yellow coronal line 5694 Å after the flare. The spectrograms were obtained at a distance of 40" from the Sun's edge in the position angle interval 275 — 300°. As may be seen from the drawing, the line 5303 brightness increased by 3 — 4 times after the flare in the region where the limb flare took place. The glow of the yellow coronal line 5694 (Ca XV) also took place in that region. Two maxima are noted in the glow of this line, while the second maximum is shifted by 10 — 12° from the center toward the higher latitude side. An analogus pattern of the shift of line 5694 Å glow maximum relative to the spot was observed by Waldmeier [6]. He found that shift to be 5° toward the side of higher latitudes.

Another observation of the rare glow of the yellow coronal line was conducted by us on 28 September 1961. We observed in the course of a series of days a group of spots having gotten close to the edge on 28 September in the position angle region of 277°, Aside from the spot group, a long filament was observed on the disk, which disintegrated during the same day.



spot filament

Fig. 5

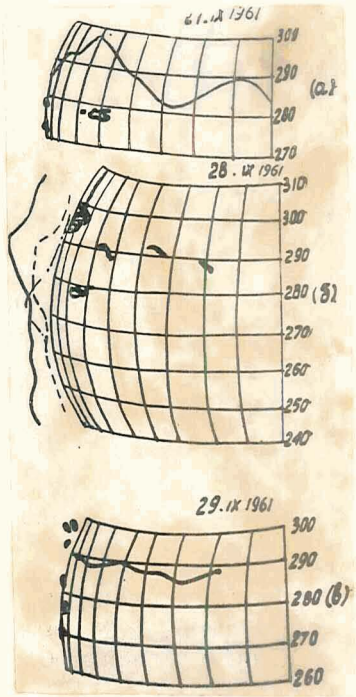


Fig. 6

A map with the spots, the filament and the prominences for the three days of observations is presented in Fig. 6.

On 27 September (a) a long filament was observed directly from the western edge to the center of the Sun. In the position angle region of 285°, where the filament ends, prominences were absent on the limb despite the presence of the filament directly at the edge of the disk. Small prominences exist in the 280, 270° region. At $l \sim 80°$ and $\varphi \sim 20°$ a solitary spot is seen in the region of that filament. A group of 4 solitary spots is seen in

the region $\varphi \sim +8^{\circ}$ and $\lambda \sim +47 - 50^{\circ}$. On that day the filament was steady without breaks.

On 28 September (б) the long filament, observed on the previous day, disintegrated into separate parts of which the brightest were seen in the region $\lambda \sim 20, 35^{\circ}$ with a length of 5 to 8°. The spot group came closer to the edge, the average latitude 75°. The number of spots remained the same. No prominences of any kind were observed at the edge of that region. Apparently some violent processes took place in the chromosphere and photosphere with the result that the filament disintegrated into separate parts and the prominences disappeared. On September 28 spectrograms of the yellow coronal line of 5694 Å wavelength were obtained by the coronograph aside from the green line 5303 Å and the red coronal line 6374 Å. This was connected with the fact that at that time the spots reached closer to the edge and the filament disintegration was noted in the chromosphere-photosphere telescope.

On 29 September (с) a reconstitution of the long filament was noted, although somewhat displaced in latitude by comparison with the 27 September position. Coronal-type prominences were observed at 295° latitude in the form of four clusters. A separate compact prominence was seen in the 283° region. On that day the spots were at the very edge, the forward three having passed on the other side of the disk. On the visible part of the Sun's surface only a solitary spot and part of the filament linked with the spot group are observed.

The result of photometry of the three emission lines 5303, 6374, 5694 Å, obtained on 27 and 28 September are brought out in Fig. 7. The line intensity values are in ordinates in equivalent width values. The latter are given from the right

for the green coronal line, and from the left for the lines 5694 and 6374 Å. The position angles, at which observations were conducted are in the abscissa axis, where besides the spot and filament regions are indicated.

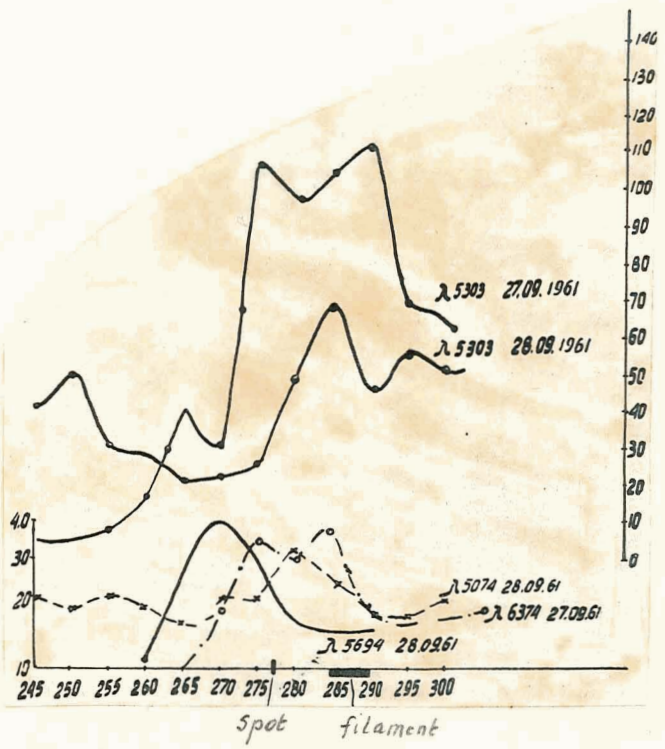


Fig. 7

It follows from Fig. 7 that the green coronal line 5303 Å was somewhat brighter on 27 September. However, in spite of a weakening of the glow a certain brightness redistribution along the position angle has taken place.

The same occurred with the red coronal line 6374 Å. If this line was glowing in the 265-300° region on 27 September, on the 28th it encompassed the position angle interval of 245-300° and more.

The yellow coronal line 5694 Å glows in the 260-295° region with a maximum near 270°. Its maximum glow is displaced

by 7 — 8° from the spot region. As in the first case of 12 July 1961 the glow region of the line 5694 Å was broader on 28 Sept. than the region occupied by the spot.

Another characteristic though not very substantial phenomenon is the strenghtening relative to the preceding day of the glow of the red coronal line 6374 A belonging to iron Fe X.

Thus the simultaneous glow of the line 5694 Å belonging to Ca XV , with a high (814 eV) ionization potential, and of the line 6374 Å with lesser ionization potential (213 eV), took place in the thickened matter above the active regions occupied by spot groups and the disintegrated filament, as a result of strong variations of underlying layers. This corroborates once more the validity of Elwert's results [7] on the existence in a single spot of various ions with strongly differing excitation potentials.

We note in conclusions that on the basis of the material obtained, the following deduction may be made :

1. The yellow coronal line of 5694 Å wavelength is more actively manifest in the flare region, being by 8 — 10° distant from the spots and occupying a substantially greater space than the spots.

2. In certain cases lines of different ionization potentials may coexist, thus corroborating the theoretical viewpoint of Elwert despite some contradiction in structural photographs [8].

***** THE END *****

Translated by ANDRE L. BRICHANT
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27 January 1963

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